HAWAII
APRIL 2010

Forest Health 2009 highlights

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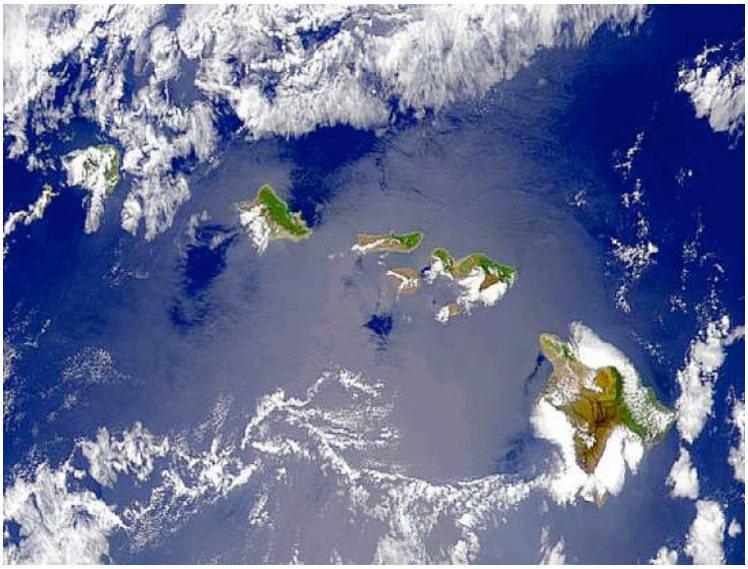
Forest Resource Summary

The State of Hawaii includes eight main islands (Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, Hawaii, and Niihau) totaling 4.1 million acres. Public lands occur on all islands except Niihau and Lanai, which are privately owned. Approximately 1.4 million acres of the state are considered forested. Non-forested areas include urban and agricultural areas, recent lava flows, and high elevation sites on Mauna Kea and Mauna Loa on the island of Hawaii and Haleakala on the island of Maui.

The State of Hawaii manages 1,155,900 acres including 643,134 acres in forest reserves and 109,164 acres in the state's Natural Area Reserve System (NARS) making Hawaii's state forest the 11th largest in the nation. The NARS was created to preserve unique native Hawaiian ecosystems and is also managed by the Division of Forestry and Wildlife. Federal lands account for 671,600 acres and are managed by the Department of Defense, National Park Service, and US Fish and Wildlife Service. The National Park Service is the largest federal landowner managing 365,000 acres. There are no lands in Hawaii managed by the US Forest Service. The remaining land – 2,272,000 acres – is privately owned. Increasing amounts of private forestlands in mountainous areas are being managed for watershed conservation in concert with publicly owned lands under established partnerships. These watershed partnerships manage upland areas comprising a patchwork of federal, state, and private parcels. They currently manage a combined total of 1.8 million acres throughout the state.



Forest Health Monitoring in Hawaii

Monitoring of forest health conditions occurs throughout the state on private, state, and federal lands. Monitoring objectives include the spread and impact of invasive plants, invertebrate pests, diseases, biological controlagents, and ungulates. Ground surveys, transect monitoring, helicopter surveys, road surveys, photo points, and remote sensing are techniques used to gather data.

Monitoring forest health in Hawaii presents many challenges associated with its climate and geology. Hawaii's extremely rugged terrain limits ground access to many areas and increases the difficulty of remote monitoring due to vertical slopes and shadow effects. Watersheds can have as much as half of total land area in near-vertical slopes. The exceptionally rugged terrain creates extreme temperature and rainfall gradients that result in diverse ecosystems in close proximity. These transitions occur over a very small scale making monitoring data collected over extensive areas very difficult to interpret. Identifying species as well as classifying them as diseased or infested is a complex and difficult task. Additionally, a thick layer of clouds present much of the year often limits or prohibits remote sensing and aerial surveys of mountainous areas where much of Hawaii's forests are located.

New technologies are helping resource managers in Hawaii monitor and control invasive plants. On the island of Kauai, a collaborative project with The Nature Conservancy and a private company, Resource Mapping Hawaii (RMH), has explored the use of specialized aerial photography for detecting individual invasive plants in the forest, controlling them with either ground- or aerial-based treatments, and monitoring treatment efficacy. RMH had developed a dual scale approach

Aerial photograph showing the ability to distinguish between Australian tree fern (*Sphaeropteris cooperi*) and the native tree fern hapu'u (*Cibotium* spp.) on Kauai. Photo: Resource Mapping Hawaii

to mapping that includes collecting one set of multispectral data at 15cm horizontal resolution and one set of natural color images at 2cm horizontal resolution. These data acquired by cameras mounted to fixed-wing aircraft can be used to detect certain species consistently from the air. While this technology has been integrated into management of invasive species such as Australian tree fern on Kauai, on-going work on Oahu, Maui, and Hawaii will determine whether priority invasive plants on those islands can be similarly mapped, controlled, and monitored.

Rust (*Puccinia psidii*) on 'ōhi'a seedling

Ohia Rust

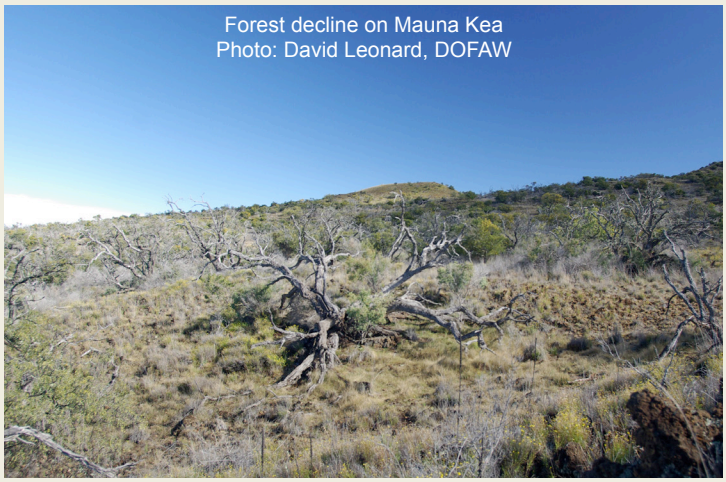
Puccinia psidii

A rust disease on 'ōhi'a lehua (*Metrosideros polymorpha*) seedlings was first detected in a nursery on Oahu in 2005. The same disease was later found infesting rose apple (*Syzygium jambos*) growing in forests on Oahu. The disease was eventually identified through DNA analysis as *Puccinia psidii*, commonly known as "guava rust" in Florida and as "eucalyptus rust" in Brazil. The disease is referred to locally as "'ōhi'a rust" because of the importance of this native tree, but it infects many species of Myrtaceae present in Hawaii, in addition to 'ōhi'a. The disease is present on all major islands and is likely to have spread between islands by wind and the movement of ornamental plants.

Drought

Much of Hawaii is experiencing severe drought conditions, with leeward Maui and the Big Island being especially hard hit. The mamane (*Sophora chrysophylla*) forests on the leeward slopes of Mauna Kea support the last remaining population of the endangered palila, the last of the finch-billed honeycreepers found on the main Hawaiian Islands. Palila rely almost entirely on the green seeds of mamane for food, and unfortunately these trees are experiencing reduced flowering and seed production due to severe drought stress this year. The drought and bark stripping and browsing of foliage by non-native ungulates are contributing to the overall decline of this forest, despite efforts to control them. Invasive plant cover prevents mamane recruitment leaving only old, senescent trees. In addition, Armillaria disease (*Armillaria nabsnona*) has been found on both native mamane and introduced pines (*Pinus* spp.), although pathogenicity studies are needed to determine its role in the decline of the forests. Finally, the threat of fire is of considerable concern; especially give the current drought conditions.

Increased incidence and duration of fire is a direct result of drought in Hawaii, where most native vegetation is not adapted to fire. Burnt vegetation is quickly replaced with fire-promoting grasses such as fountain grass (*Pennisetum setaceum*), an invasive grass widely established on the west side of Hawaii. As forest vegetation is replaced with fire-promoting invasive grasses the cycle continues, destroying native vegetation. Hawaii's dry forests are especially impacted, with only 5% of this ecotype remaining today.



Forest decline on Mauna Kea
Photo: David Leonard, DOFAW

Drought often interacts with forest pests to negatively affect forests. For example, the recovery of gall wasp-infested wiliwili (*Erythrina sandwicensis*) forests is being hampered in Waikoloa on the island of Hawaii, despite the successful establishment of a biological control there (see Erythrina Gall Wasp, page 4). Outbreaks of pests such as the black twig borer (*Xylosandrus compactus*) and the Eucalyptus longhorn beetle (*Phoracantha semipunctata*) tend to occur when forests are drought-stressed.

Confirmed host species of *Puccinia psidii* in Hawaii

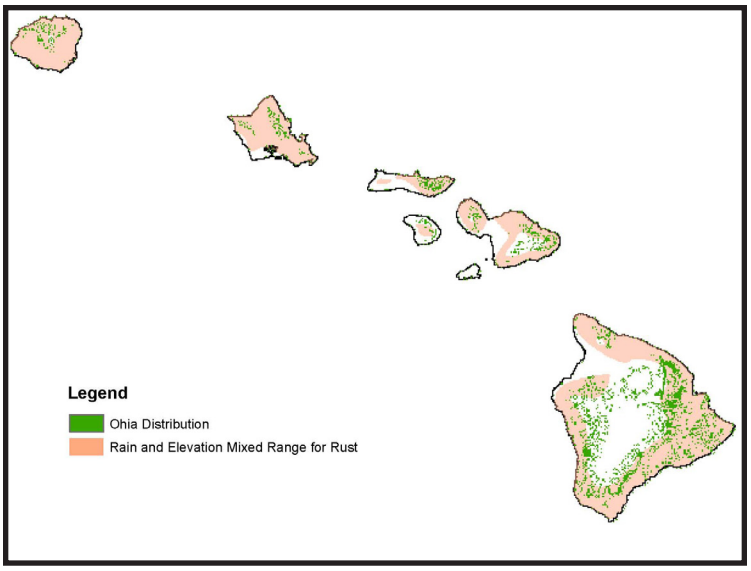
Scientific Name	Common Name
Calistemon citrinus	Bottlebrush
Chamelaucium uncinatum	Waxflower
Eugenia koolauensis (H)	Nioi
Eugenia palumbis	Agatelang
Eugenia reinwardtiana (H)	Nioi/Beach cherry
Eugenia uniflora	Surinam cherry
Melaleuca quinqeunervia	Paper bark
Metrosideros excelsa	Pohutukawa
Metrosideros kermadecensis	Kermadec pohutukawa
Metrosideros polymorpha (H)	‘ōhi’a lehua
Metrosideros tremuloides (H)	‘ōhi’a lehua
Myrciaria cauliflora	Jaboticaba
Myrtus communis	True myrtle
Pimenta dioica	Allspice
*Psidium guajava**	Common guava
Rhodomyrtus tomentosa	Downy rosemyrtle
Syzygium cumini	Java plum
Syzygium jambos	Rose apple
Syzygium malaccense	Mountain apple
Syzygium paniculatum	Australian brush cherry
*Syzygium sandwicensis** (H)	Ohia ha

(H) Native to Hawaii
* Host only found infected once at low level

The disease infects young leaf tissue producing bright yellow pustules and causes stunting and shoot dieback on the plant. In some species it also infects flowers and fruits. The rust rarely kills its host, except for rose apple which is extremely susceptible and is currently dieing off across Hawaii’s watersheds. Susceptibility of hosts varies widely among species. Infections on ‘ōhi’a have been reported mostly in nurseries where either environmental conditions or abundance of young, susceptible foliage appears to be conducive to outbreaks of the rust. Some ‘ōhi’a varieties do not develop symptoms when growing in infested nurseries. Detections of the disease in native forests have been at very low levels and at elevations under 4,500 feet, and it does not appear to be strongly impacting ‘ōhi’a forests at this point.

An Evaluation Monitoring Survey funded by Forest Health Monitoring was completed by University of Hawaii in 2008. Disease locations in forestlands throughout the state were compiled and disease hosts were documented (see above table). Disease presence has been confirmed on all major islands at elevations as high as 4,500 ft where hosts are present (’ōhi’a’s range extends above 7,000 ft on Hawaii and Maui). The disease was reported on 21 different species, 5 of which are native to Hawaii, including the federally listed endangered *Eugenia koolauensis*. In addition, several species including *Eucalyptus* spp. have been artificially inoculated using inoculum isolated from rose apple in the laboratory, however eucalypts have not been found infected in the environment

The disease is a serious threat to Hawaii’s native forest. ’Ōhi’a is the dominant tree species in much of Hawaii’s remaining native forests and provides important habitat for endangered plants and birds as well as vegetative cover for much of



Range of ‘ōhi’a (*Metrosideros polymorpha*) overlayed with the climatic and evevational range of *Puccinia psidii* as determined by survey collected by Robert Anderson.

Hawaii’s watersheds. Adaptation and increased virulence of the rust disease on ‘ōhi’a is a possible development. Commercial eucalyptus plantations could also be threatened, especially as plantations are harvested and replanted. (The island of Hawaii has approximately 20,000 acres in commercial eucalyptus plantations). *Eucalyptus* seedlings of commercial species such as *E. grandis* are very susceptible to damage from *P. psidii* in Brazil, although susceptibility in laboratories in Hawaii to local inoculum was found to be minimal on *E. grandis*.

Preliminary DNA analysis by University of Hawaii and Forest Service researchers suggests that the disease strain in Hawaii is a single strain and is different from strains in Florida and Brazil. Work is underway to create a phylogenetic map of the disease in Hawaii, mainland U.S., the Caribbean and South America in collaboration with Universidade Federal de Vicosa, Brazil, the University of Hawaii, and the USDA Forest Service, Rocky Mountain Research Station. Different strains with different host-ranges have been observed and can vary in virulence. ‘Ohi’a seed was sent to collaborators in Brazil to conduct inoculation tests with strains identified there in the phylogentic mapping project.

The State of Hawaii, Department of Agriculture, interim quarantine restriction on imported Myrtaceae plant material ended in August 2008. Currently all Myrtaceae material arriving from the mainland U.S. is inspected for disease. Ongoing monitoring will help detect introduction of new disease strains into Hawaii.

Koa Wilt
Fusarium oxysporum f.sp. *koae*
Koa wilt disease was first described in 1980 on the island of Hawaii and was attributed to the pathogen *Fusarium oxysporum* f.sp. *koae*. The pathogen infects trees through their roots and causes damage to the vascular system, sometimes leading to crown dieback and tree death. It is not known where the disease originated or how the disease spreads in the environment. Other areas of koa dieback were reported

throughout the state thereafter, but little work had been carried out on the disease until the last few years despite the ecological, cultural, and economic importance of koa to the state of Hawaii.

Although wide-scale dieback has not been observed in forests, there has been a high incidence of the disease causing high mortality rates in koa plantations, especially on former agricultural lands. A survey for koa wilt was conducted in 2004-2005 by the Hawaii Agriculture Research Center and DOFAW with funding from USDA Forest Service Forest Health Protection. The survey located areas with symptomatic trees and collected root, stem, leaf, and seed samples for isolating *F. oxysporum* in the laboratory. Diseased trees were sampled in both plantations and natural forests throughout the state.

Dead or dying trees testing positive for *F. oxysporum* were found on all of the major islands where koa commonly grows. Trees in both planted and natural forests were found infected with koa wilt disease. *F. oxysporum* was found most commonly on roots and soil near diseased trees. Interestingly, other *Fusarium* species were also isolated from sampled tissue, and pathologists are exploring the role of these other species in the disease etiology. Methods of sampling for the disease were refined in this survey facilitating future survey and monitoring for the disease. Outreach materials on koa wilt were developed by the University of Hawaii and can be found at: http://www.ctahr.hawaii.edu/forestry/index.asp.

Many questions remain unanswered regarding koa wilt. The extent of the disease in natural forests is not known, nor is whether the pathogen exists in healthy forests. Knowing how the disease spreads in the environment is also crucial for management. In a 2007 survey of nurseries that provide planting stock to conservation areas, *F. oxysporum* along with other *Fusarium* spp. was found prevalent on koa seedlings.

What appears to be genetic resistance has been observed

Inoculation trials on koa (*Acacia koa*) for resistance to *Fusarium oxysporum* f.sp. *koae* at Hawaii Agriculture Research Center on Oahu

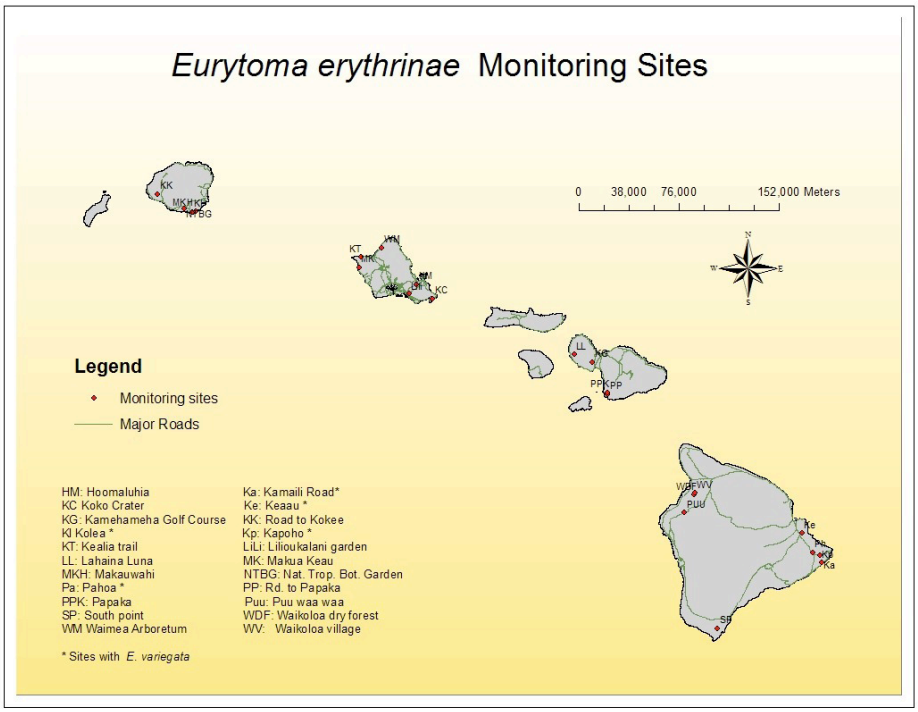
Dead wiliwili tree (*Erythrina sandwicensis*) in highly damaged stand on Oahu

in koa plantations trials, and efforts to develop genetic resistance are being pursued by Hawaii Agriculture Research Center. Koa families from each island are being screened for resistance by inoculating seedlings with pathogenic strains of *F. oxysporum*. Resistant families will be planted in seed orchards on respective islands to provide seed for plantings. Techniques are being developed to propagate koa vegetatively to accelerate development of disease resistance.

Erythrina Gall Wasp
Quadrastichus erythrinae

The Erythrina gall wasp (*Quadrastichus erythrinae* Kim) was first detected in 2005 as galls on leaves and stems on ornamental Indian coral trees (*Erythrina variegata*) at the University of Hawaii campus on Oahu. Emergent adult wasps were then positively identified as *Quadristichus erythrinae* Kim, a species only recently described (2004) from specimens from Singapore, Mauritius and Reunion. The current distribution of the Erythrina gall wasp (EGW) includes Taiwan, mainland China, India, American Samoa, Guam, and Florida. Adult wasps show a preference for ovipositing in young tissue and galls have been observed on leaves, petioles, young shoots, stems, flowers and seed pods. Generation time is rapid: the life cycle of the wasp (egg to adult) has been observed as short as 21 days in Hawaii; the adult's life span varies from 3-10 days.

Once introduced, the tiny wasps were easily dispersed by wind and the movement of people and goods, and spread rapidly to



Pre- and post-release monitoring of biological control for the Erythrina gall wasp (*Quadrastichus erythrinae*)

all neighboring islands where host species are present (Hawaii, Kahoolawe, Maui, Molokai, Lanai, Oahu, Kauai, and Niihau). Most *Erythrina variegata* trees have been killed and removed. *Erythrina crista-galli*, also a common landscaping tree, is more resistant and trees continue to survive with minimal infestation.

The native wiliwili (*Erythrina sandwicensis*) is the dominant tree species in most of Hawaii's dry forests. Although still considered abundant, little regeneration of wiliwili is occurring due to widespread seed predation by the bruchid (*Specularis impressithorax*), competition from introduced grasses, fire, and severe browsing pressure by introduced ungulates, in addition to the recent outbreak of Erythrina gall wasp. The impact of the gall wasp on natural wiliwili populations is variable; some populations are still relatively healthy while others are moderately to highly infested with mortality as high as 50% in some stands.

Biological control was aggressively pursued by the Hawaii Department of Agriculture (HDOA) and the University of Hawaii. After initial exploratory trips to Africa, several potential agents were tested in containment facilities in Hawaii. The first agent, a wasp in the family Eurytomidae, was released in 2008 by HDOA at several wiliwili populations throughout the state to control the gall wasp. The adult eurytomid wasp oviposits on galls; when its eggs hatch, the larvae consume the larvae of EGW. The biocontrol wasp spread quickly and has established throughout the state. Parasitism rates of EGW larvae inside galls were consistently around 90%. Galling levels on wiliwili trees have been reduced considerably and they appear to be recovering. In some areas managers are beginning to outplant wiliwili in restoration sites again. Ongoing monitoring in collaboration with the HDOA and UH will continue to assess the impact of the released biocontrol on the health of the wiliwili trees. Two other agents found in Africa are currently being held in containment facilities in Honolulu for future release if necessary.

Myoporum Thrips

Klambothrips myopori

A new insect pest, myoporum thrips, was detected on naio (*Myoporum sandwicense*) the island of Hawaii in early 2009. Myoporum thrips was first described in California when it showed up in 2005 infesting landscape plantings of *Myoporum laetum* from New Zealand. Its origin remains unknown although most species in the genus are native to Australia. On the big island it was found infesting naio papa, a low-growing variety planted along roadways in resort areas in South Kohala

Cynthia King (DOFAW entomologist) monitoring success of biological control of the Erythrina gall wasp (*Quadrasticus erythrinae*) on wiliwili tree (*Erythrina sandwicensis*) on the island of Hawaii

Damage to naio (*Myoporum sandwicense*) by myoporum thrips (*Klambothrips myopori*)

and North Kona districts, where the climate is very dry. Hawaii Department of Agriculture and the Big Island Invasive Species Committee carried out surveys to determine the extent of the infestation. The infestation was determined to be too extensive to be eradicated; the thrips had likely been moved between resorts by landscape companies. No natural populations of naio were found infected.

Damage to the host in California has included complete defoliation and sometimes plant death. The areas infested in Hawaii were not as extremely affected as they were being treated with insecticides. The damage resembles galling and can lead to stunting of shoots. While insecticides have been found to be effective in controlling myoporum thrips damage (Dr. Arnold Hara, pers. comm.) widescale treatment of naio in natural areas is not practical. The development of biological control is unlikely to happen quickly, as the pest has yet to be identified in its native range.

Naio is a small tree or shrub that grows in a wide variety of ecosystems throughout Hawaii, from arid coastal strand communities to high elevation wet forests. On Mauna Kea on the big island, naio and mamane (*Sophora chrysophylla*) are codominant trees making up a forest that is the last remaining habitat for the endangered palila. If the species were to suffer dieback due to this pest, a wide range of damage to ecosystems would result.

Recently, myoporum thrips were detected in natural areas on the big island causing stunting of shoots on several trees. The site will continue to be monitored. A survey funded by Forest Health Monitoring will determine the impact on naio, climatic and seasonal affects on pest damage, presence of natural enemies, and interaction with other pests. Early detection surveys of nurseries and natural populations are being carried out on the other islands by Hawaii Department of Agriculture, DOFAW, and invasive species committees.

Miconia (*Miconia calvescens*), which was introduced to Hawaii for its beautiful foliage, is an invasive species committee priority target.

Early Detection and Rapid Response

Early detection is the best prevention against invasive species. Hawaii is unique in its extreme isolation from other terrestrial biodiversity centers. Once an invasive species becomes established in the state, individual islands may remain free of pest species through intra-state quarantine practices and constant monitoring, followed by effective control, leading to island-wide eradication. Island-wide eradication is the most cost-effective, long-term protection for native ecosystems.

The lead organization on early detection and rapid response of invasive plants are the island-based invasive species committees. Hawaii's invasive species committees (ISCs) became active in the 1990s with the goal of being able to respond to threats of alien pest infestations and to control established pest populations on a species by species basis. The Maui Invasive Species Committee (MISC), the Molokai subcommittee of MISC (MoMISC), the Big Island Invasive Species Committee (BIISC), the Kauai Invasive Species Committee (KISC), and the Oahu Invasive Species Committee (OISC) are already well involved in the battle against invasive species. Each ISC is a voluntary partnership of county, state, and federal agencies, private businesses, nonprofit organizations, and individuals united in cooperative efforts to control alien pest species that pose the greatest threats to each island's ecosystems, watersheds, economy, public health, and quality of life.

The ISCs work to prevent incipient species from becoming established in Hawaii's watersheds and natural areas. While the ISCs' geographic scope is island-wide, much of their work is focused in the lower elevation areas, at or near the boundaries of conservation lands, on residential or rural properties, or on disturbed forest lands where incipient populations of invasive species are found. When the ISCs work in forested mountain areas, they often collaborate with the Watershed Partnerships. ISCs typically do not work on controlling species such as pigs or goats, which are both widespread and not good candidates for species-based management.

Further information on the ISCs and the work they do can be found at http://www.hawaiiinvasivespecies.org.

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Managing Widespread Invasive Plants

In contrast to the ISCs' "species-led" management, many entities in the state carry out "site-led" or "area-based" management of established invasive species to protect high-value conservation areas. Examples include Hawaii's Watershed Partnerships, the National Park Service, The Nature Conservancy of Hawaii, the Department of Defense, and DOFAW's Natural Area Reserve System. The species these groups control are usually too widespread to be eradicated and must be managed strategically across the landscape requiring collaborative management.

The Watershed Partnerships were formed to better manage natural resources across property boundaries in Hawaii. The partnerships include state land managers such as DOFAW, federal agencies like the National Parks, non-profits such as The Nature Conservancy, and large private landowners. Eleven partnerships have formed on all of the main Hawaiian islands and employ staff to carry out conservation projects.

Watershed partnerships spend much of their time and resources controlling invasive species that threaten important watershed areas. Fences are constructed around important conservation areas to prevent damage by feral ungulates such as pigs, which also serve as vectors for invasive plants. Examples of invasive plants targeted for control include strawberry guava, clidemia, Kahili ginger, and tibouchina. These species threaten the health of watersheds by reducing the amount of recharge and creating erosion. Targeted species are monitored and controlled using manual, chemical, and sometimes biological control.

Further information on Hawaii's Watershed Partnerhsips can be found at http://www.hawp.org.

The vegetation on the south slope of Molokai has been destroyed by feral goats. During heavy rainfalls, the soil is washed down to the coast, where the silt impacts the coral reef.

Biological Control

Many of the established invasive species in Hawaii will only be managed effectively in the long-term with the use of safe and responsible biological control. The USDA Forest Service, the University of Hawaii, and the Hawaii Department of Agriculture carry out biological control development essential to invasive species management in the state. Two containment facilities in the state – one in Honolulu and one in Hawaii Volcanoes National Park – are available for conducting studies on biological control agents. The containment facility in Honolulu is also approved for the study of pathogens.

Scientifically rigorous testing is conducted on all potential agents to ensure that no negative environmental affects occur when an agent is finally released into the environment. Since these scientific protocols along with government regulations were put into place in the 1970's, biological control has been 100% free of damaging effects.

Unfortunately, resources in the state have long been insufficient for developing biological control against the dozens of potential targets. The backlog of projects worsened when Hawaii Department of Agriculture's Plant Pest Control branch lost 40% of its staff for biocontrol and entomological surveys due to state budget shortfalls last year. Many people in the state still mistakenly equate the century-old introduction of the mongoose to Hawaii with biological control, tarring its image as a safe and cost-effective tool for managing invasive species.

In spite of these hurdles, there was progress in biological control the past year. Ongoing projects made significant advances toward developing new biological control agents for miconia, clidemia, tibouchina and kahili ginger. International cooperation toward sustainable management using biocontrol was a key focus of the International Miconia Conference on Maui in 2009, and new collaborations with biocontrol researchers in Australia are expected to arise as a result. Outreach to communities on Hawaii, Maui, Oahu, and Kauai provided information on a proposed introduction of an agent for strawberry guava (*Psidium cattelianum*), one of Hawaii's worst forest invaders. The control agent, a gall-forming scale, has been studied extensively by the Forest Service and found completely specific to strawberry guava. The environmental review of the release is ongoing, but managers hope the insect becomes an available tool for managing strawberry guava soon.

The successful introduction of a biological control agent for the Erythrina gall wasp (see page 4) provides an excellent opportunity to educate people about biocontrol because this pest caused highly visible damage to trees throughout the state. Invasive species public outreach staff from various organizations have been working together to develop a communication strategy for biocontrol and to discover new ways to engage the public on this important, yet sometimes controversial management tool.

Syphraea larvae feeding on *Tibouchina herbacea*.
Photo: Tracy Johnson, USDA Forest Service

Contacts and Additional Information

Data Sources

The data sources used for this report include data gathered by Hawaii's island-based Invasive Species Committees or ISCs (funded in part by USDA Forest Service, Forest Health Protection, Prevention and Suppression Program), Division of Forestry and Wildlife staff, Hawaii Department of Agriculture, University of Hawaii, and partner organizations such as the Hawaii Agriculture Research Center. Survey and monitoring data collected by the ISCs are entered into a statewide database created by the USGS Pacific Basin Information Node, and the data are analyzed at the local and state levels.

Hawaii's Watershed Partnerships, the National Park Service, The Nature Conservancy of Hawaii, and DOFAW's Natural Area Partnership System also conduct monitoring of invasive plants and ungulates to improve the effectiveness of their management activities, but those data are not the focus of this report. The USDA Forest Service's Forest Health Aerial Survey Program and Forest Inventory and Analysis Program are not currently active in Hawaii.

Authors

- Rob Hauff, Forest Health Coordinator, Hawaii Division of Forestry and Wildlife (DOFAW)
- Mindy Wilkinson, Invasive Species Coordinator, DOFAW
- Anne Marie LaRosa, Forest Health Coordinator, USDA Forest Service, Pacific Southwest Research Station

United States Department of Agriculture